Unusual photon isospin mixing and instantaneous Coulomb effects on the thermodynamics of compact matter

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A hidden local symmetry formalism with a two-photon counterterm approach is performed based on the relativistic continuum quantum many-body theory. The underlying electromagnetic underscreening as well as screening effects between the electric charged point-like electrons and composite protons are discussed by analyzing the in-medium isospin mixing of Lorentz vector with scalar due to electromagnetic photon. Besides the usual screening results, the main conclusion is that an effective oscillatory instantaneous Coulomb potential between the like-charged collective electrons contributes a very large negative term to the equation of state. This counterintuitive like-charged attraction results from the modulation factor of the opposite charged baryon superfluid background. The anomalous long distance quantum dragging effects between the collective electrons can be induced in a compact Coulomb confinement environment. The physics is of the strongly coupling characteristic in a specific dilute regime.

I. INTRODUCTION

Intriguingly, it is usually assumed that there is a uniform positive background to ensure the stability in discussing the thermodynamics of electrons system. This is the well-known (generalized) Thomson Problem for over a century. Of course, there is not a finished standard answer up to now[1]. In nuclear physics, the status quo is an *inverse* one. The electrons are usually taken as a uniform negative charged background and further treated as the ideal degenerate gas with the notion that the nuclear force is of electric charge independent. Furthermore, it is customarily accepted that the weak Coulomb contribution is well known or screened out and can be turned off by taking the point-like picture of protons. What physics will be found or answered if considering the interactions between the two opposite charged subsystems?

The realistic nuclear matter is subject to the long range electromagnetic(EM) interaction. The infrared EM Coulomb force between the charged particles such as electrons and composite protons makes the discussion of thermodynamics or equation of states(EOS) even more involved and may lead to rich physics[2, 3, 4, 5]. In addition to the (residual) strong interaction contribution to EOS, the EM fluctuation/correlation effects are very important to the mechanical, thermal, chemical equilibrium conditions and further influence the various transport properties of the compact star nuclear matter due to Coulomb "frustration" effects (for example, see Refs. [5] and references therein). This kind of frustration effects will lead to the strongly coupled picture physics which belongs to the non-perturbative context. The hitherto overlooked but important EM force can even significantly af-

fect the single particle energy spectrum as recently found with the study of some mirror nuclei, which provides evidence for the inclusion of the novel electromagnetic spin-orbit effect[6]. To our knowledge, the EM correlation is still a challenging task in many-body theory and even for finite nuclei[7].

The effective relativistic continuum nuclear theory provides a powerful theoretical framework to account for the various exotic many-body properties of neutron-star nuclear matter or finite nuclei[8, 9]. The pairing correlation calculations of neutrons and protons in nuclear matter inspired by the quite different empirical negative scattering lengths in free space between nucleons promote us to assume the spontaneous breaking analogously to the EM $U(1)$ gauge symmetry breaking concept of Anderson-Higgs mechanism in order to gauge the infrared singularity[10, 11]. This is the Lorentz spontaneous violation according to the standard notion, which is currently the central topic of cosmology etc.[12, 13]. The theoretical spinodal instability and uncertainty can be removed consequently with the in-medium Lorentz violation notion.

The electron density becomes very diluter(hence strongly correlating according to statistical physics) compared with the baryon density when one takes into account the charge neutralized condition[11]. It remains an intriguing task to deal with the strongly correlated electrons ground state energy simultaneously with that of nucleons, which is closely related with the neutron star crust or supernova explosion physics in the dilute regime. Needless to say, this is a fundamental/difficult problem to tackle analytically in the general many-body context.

To address the charge neutralized strongly interacting system thermodynamics with the net electric charged chemical potential based on the relativistic continuum field theory formalism, we propose a compensatory two-photon method with the Hidden Local Symmetry(HLS)

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formalism to remove the infrared singularity. Surprisingly, the exact ground state energy solution of collective electrons manifests a counterintuive long range attraction picture in the strongly coupling limit, which is far from the starting point in order to unveil/answer the realistic physics motivation presented in Ref.[11].

The plan of this work is as follows. In Section II, the isospin mixing effect of photon with sigma meson(short range nuclear force) leading to under-screening is analyzed. The consequent novel quantum fluctuation effects on the strongly correlated electrons thermodynamics in a dilute compact confinement environment is discussed in Section III. The discussions are made in Section IV. The final SectionV presents the conclusion remarks.

II.   ISOSPIN MIXING OF PHOTON WITH SIGMA MESON

To make the constructive two-photon Thomson Problem counterterm scheme presented in the next section more comprehensive, we will firstly reveal the unusual polarization properties that are often overlooked. The discussions will give us a strong inspiration, i.e., there is the possible EM under(anti-)screening effects in addition to the usual screening in a compact environment. The expected conventional weak coupling perturbative expansion and/or resummation based on the exclusive screening of normal state cannot be valid any more in addressing the strongly coupling limit thermodynamics.

In addressing the low energy long wavelength thermodynamics, it is a good approximation to take the nucleon as a point-like particle according to the effective field theory's idea[8]. With this picture, one can perform the polarization tensor calculation with the in-medium protons[14]. Essentially, according to particle physics, one can introduce the isospin concept for photon γ. Therefore we can study the nontrivial in-medium isospin mixing of γ and sigma meson σ following the well discussed $\sigma-\omega$ mixing etc., from which the full propagators of γ and σ can be simultaneously determined with the mixing polarization tensor Π, a 5×5 matrix[15].

With Π, the dielectric function in the presence of mixing to determine the collective modes or study the screening effects is

$$\epsilon(k_0, |\mathbf{k}|) = \epsilon_T^2 \times \epsilon_{mix}, \tag{1}$$

where ϵ_T corresponds to the two identical transverse (T) modes and ϵ_{mix} to the longitudinal mode (L) of the photon with mixing. Furthermore, one can analyze the nontrivial mixing effects on the inter-particle EM correlation physics between the charged particles with the effective permittivity, which is reduced to

$$\epsilon_{eff}(0, |\mathbf{k}| \to 0)$$
$$= 1 + \frac{1}{\mathbf{k}^2} \left(\Pi_P^L(0,0) + \frac{1}{m_\sigma^2 + \Pi_{N,P}^\sigma} (\Pi_P^{\sigma-\gamma,0})^2 \right). \tag{2}$$

In Eq.(2), the polarization tensor components are calculated via the following selfenergies

$$\Pi_{N,P}^\sigma(k) = 2g_\sigma^2 T \sum_{p_0} \int_p \text{Tr} \left[\frac{1}{\not{p} - M^*} \frac{1}{(\not{p} - \not{k}) - M^*} \right],$$

$$\Pi_P^{\sigma-\gamma,\mu}(k) = eg_\sigma T \sum_{p_0} \int_p \text{Tr} \left[\frac{1}{\not{p} - M^*} \gamma^\mu \frac{1}{(\not{p} - \not{k}) - M^*} \right] \tag{3}$$

$$\Pi_P^{\gamma,\mu\nu}(k) = e^2 T \sum_{p_0} \int_p \text{Tr} \left[\gamma^\mu \frac{1}{\not{p} - M^*} \gamma^\nu \frac{1}{(\not{p} - \not{k}) - M^*} \right],$$

with the shorthand notation $\int_p = \int d^3\mathbf{p}/(2\pi)^3$ and $p_0 = (2n+1)\pi T i + \mu^*$ while μ^* and M^* being the effective chemical potential and fermion mass, respectively. The $\Pi_e^{\gamma,\mu\nu}$ for the electron-loop self-energy is similar to $\Pi_P^{\gamma,\mu\nu}$.

The standard calculations of the self-energies including the Dirac and Fermi's sea contribution at finite temperature can be found in Ref.[16]. Here in this work, concentrating on the density fluctuation effects and relevant physics, we present explicitly the Fermi sea's contribution of scalar meson self-energy and the $\sigma-\gamma$ mixing polarization tensor-0 component at $T=0$

$$\Pi_P^{\sigma-\gamma,0}(0,0) = -\frac{eg_\sigma M^*}{\pi^2} k_f,$$

$$\Pi_{N,P}^\sigma(0,0) = \frac{g_\sigma^2}{2\pi^2} \left[k_f E_f^* + 3M^{*2} \ln \frac{M^*}{k_f + E_f^*} \right], \tag{4}$$

where $E_f^* = \sqrt{k_f^2 + M^{*2}}$. From Eq.(4), one can find that the static limit of the sigma meson self-energy is negative $\sim -10^6 MeV^2$ in a wide density and temperature regime enhanced by the isospin degenerate factor "2" in Eq.(3) due to the doping effects of neutrons. This can be attributed to the different isospin vector and scalar fluctuation behaviors of QCD[16].

The standard Thomas-Fermi/Debye screening masses are closely associated with EOS, which are defined according to the static infrared limit of the relevant self-energies[17]. The static limit of the e(P)-loop self-energy is the familiar formalism

$$\Pi^{00}(0,0) = -\frac{e^2}{\pi^2} k_f E_f^*. \tag{5}$$

If without considering the non-trivial mixing effect, the usual electric screening masses reflecting the weak coupling screening physics can be directly obtained through $M_D^2 = \Pi^L(0,0) = -\Pi^{00}(0,0)$. For example, at the empirical saturation density with Fermi-momentum $k_f = 256.1 MeV$ and an effective nucleon mass $M^* \sim 0.8 M_N$, the numerical results are $M_D^P \sim 43.46 MeV$ and

$$M_D^e = 24.69 MeV. \tag{6}$$

The crucial observation is that the Thomas-Fermi electric screening mass through the virtual (anti-)electron polarization calculation Eq.(5)-Eq.(6) instead of that

from the random phase approximation(RPA) P-loop one is exactly consistent with the previous estimation[11]. This scenario is also consistent with the conventional notion of plasma theory that electrons screen the long-range Coulomb force between protons or ions[4]. The either local or global charge neutralized condition is automatically ensured through the full photon propagator calculation[18].

In turn, a natural but very uncomfortable question may arise from above fortuitous but exact consistency Eqs.(5-6) is: Will the nucleons "screen" the EM interaction between the opposite charged lepton electrons?

The systematic study is non-trivial as naively expected because the solutions will involve the Debye mass that can become catastrophically imaginary. With the denominator in the bracket of Eq.(2), the term $\Pi_P^L(0,0) + (\Pi_P^{\sigma-\gamma,0})^2/(m_\sigma^2 + \Pi_\sigma)$ may be smaller than $\Pi_P^L(0,0)$ and the effective permittivity can be negative due to the isospin mixing effects of isoscalar σ and γ with the unusual sigma meson self-energy behavior Eq.(4). In deed, the Fermi-sea contribution dominates over the Dirac sea's, i.e., the in-medium/density fluctuation effects can lead to the under(anti)-screening effects[16]. The negative permittivity implies that there is a strongly coupled characteristic EM instability in a compact environment. This Fermi surface instability results from the rummy competition between the short range nuclear force attraction and the long range EM fluctuation repulsion.

In our perception, the complete isospin mixing calculations for the strongly coupled nucleons is a seriously difficult task, which we suspect will require a greater understanding of nuclear force. We do not claim to have a complete solution. Intuitively we can make an *ansatz* that the final analytical expression can be reduced to

$$\Pi_P^L(0,0) + \text{mixing contribution} = -\Pi_e^L(\mu_P^*, T_P), \quad (7)$$

which can be in principle realized through other involved isospin mixing discussions $\sigma - \omega$, $\gamma - \omega$ esp. the unclear charge symmetry breaking term $\rho - \omega$ etc. attributed to the different current quark masses which is beyond the scope of the adopted effective theory framework. These effects can be manifested through the two-photon [19] approach in an easily controllable way. The two-photon formalism as given in Sec. III will confirm this ansatz indirectly through the Thomson stability condition of the lepton electrons thermodynamics background.

With excitation concepts in plasma dielectric function theory, the modes determined by the poles of the full propagators may be spacelike and of tachyonic characteristic which is closely related to the Landau damping and consistent with the nonlinear response property. From the viewpoint of isospin mixing, the EM interactions between the point-like particles explored by the relativistic nuclear field theory are not simply/only screened and their contribution to thermodynamics cannot be neglected by naively taking the ideal degenerate gas or quasi-particle picture of normal fluid. Resulting

from long range Coulomb frustration effects, the multicomponent baryon nucleons system can be in the novel thermodynamics pasta state especially in the subsaturation nuclear density regime. The analytical exploration contributes to understanding the underlying strongly interacting Coulomb physics hidden in the diversely updating works.

III. STRONGLY CORRELATED COMPACT MATTER THERMODYNAMICS

A. Formalism

With above analysis, the isoscalar EM interaction embedded in the relativistic nuclear theory has the strongly coupling confinement characteristic which promotes us to construct a Proca-like Lagrangian to deal with the unusual quantum mechanical Coulomb effects between the charged baryon particles[11]. In this work, we attempt a two-photon non-perturbative approach to model the thermodynamics properties of the charge neutralized $Pe\nu N$ plasma with global vanishing net electric charge chemical potential. The effective theory involves the interaction of Dirac nucleons and electrons with an auxiliary Maxwell-Proca like EM field as well as the scalar/vector mesons fields

$$\mathcal{L}_{QHD-\sigma,\omega,\rho} + \mathcal{L}_e;$$
$$\mathcal{L}_{\gamma,free} = -\frac{1}{4}F_{\mu\nu}F^{\mu\nu};$$
$$\mathcal{L}_{I,\gamma-P} = \frac{1}{2}m_{\gamma,e}^2\delta_{\mu 0}A_\mu A^\mu + A_\mu J_P^\mu;$$
$$\mathcal{L}_{I,\gamma-e} = \frac{1}{2}m_{\gamma,P}^2\delta_{\mu 0}A_\mu A^\mu + A_\mu J_e^\mu. \quad (8)$$

The full description for the relevant degrees of freedom in the Lagrangian can be found in the literature[8, 11]. In Eqs.(8), the electric currents contributed by the baryon protons and lepton electrons are as follows, respectively

$$J_P^\mu = -e\bar{\psi}_P\gamma^\mu\frac{(1+\tau_3)}{2}\psi_P, \qquad J_e^\mu = e\bar{l}_e\gamma^\mu l_e. \quad (9)$$

Based on the local gauge invariant free Lagrangian, the gauge invariant effective interaction actions can be constructed by the standard way[20, 21], respectively

$$\mathcal{L}_I = -\frac{1}{4}F_{\mu\nu}F^{\mu\nu} + |D_\mu H|^2 + V(H) + A_\mu J^\mu. \quad (10)$$

The two photon mass gaps(i.e., the Higgs charge and the expectation value of the Higgs background field) are free Lagrange multiplier parameters, i.e., they should be determined by relevant thermodynamics identities and critical dynamics constraint criterions.

Based on introducing the photon isospin concept, the conventional electromagnetic current is divided into two parts: one is the baryon current contribution of electric

charged protons; the other is the lepton current of opposite charged electrons. The position permutation of the two mass gap parameters in relevant effective actions Eq.(8) makes it possible to deal with the interior EM interaction as auxiliary external field approximation one another to ensure the theoretical thermodynamics self-consistency for the two opposite charged subsystems.

B. Thermodynamics potential of strongly coupled electrons through vector condensation

The current conservation is guaranteed by the Lorentz transversality condition with HLS formalism

$$\partial_\mu A^\mu = 0, \tag{11}$$

which can be naturally realized by taking the relativistic Hartree instantaneous approximation (RHA) formalism.

As a complementarity to the discussion for the nucleons background thermodynamics[11] with the Coulomb frustrating effects, we presently limit to the thermodynamics of the strongly correlated dilute electrons (lepton) background in a dense and hot compact nuclear environment with the following effective Lagrangian

$$\mathcal{L}_{effective} = \bar{\psi}_e(i\gamma_\mu\partial^\mu + \gamma_0\mu_e - m_e)\psi_e$$
$$-\frac{1}{4}F_{\mu\nu}F^{\mu\nu} + \frac{1}{2}m_{\gamma,P}^2 A_\mu A^\mu + A_\mu J_e^\mu$$
$$+\delta\mathcal{L}_{Auxiliary\ Nuceons\ Counterterm\ Background} \tag{12}$$

The A_μ is the vector field with the field stress

$$F_{\mu\nu} = \partial_\mu A_\nu - \partial_\nu A_\mu. \tag{13}$$

In Eq.(12), m_e is the bare electron mass with the background fluctuating vector boson mass gap squared $m_{\gamma,P}^2$. In terms of finite temperature field theory with functional path integral[8, 11, 17], the effective potential reads

$$\Omega_e/V = -\frac{1}{2}m_{\gamma,P}^2 A_0^2 - 2T \int_k \{\ln(1 + e^{-\beta(E_e-\mu_e^*)})$$
$$+ \ln(1 + e^{-\beta(E_e+\mu_e^*)})\}. \tag{14}$$

The particle(charge) number density $\rho_e = 2\int_k(n_e - \bar{n}_e)$ is well defined by the *thermodynamics identity*

$$\frac{\partial\Omega_e}{\partial\mu_e}|_{A_0} \equiv -\rho_e. \tag{15}$$

The tadpole diagram with photon self-energy for the full fermion electron propagator leads to

$$A_0 = -\frac{e}{m_{\gamma,P}^2}\rho_e, \tag{16}$$

from which the effective chemical potential μ_e^* is defined with a gauge invariant manner[4]

$$\mu_e^* \equiv \mu_e + \mu_{e,I} = \mu_e - \frac{e^2}{m_{\gamma,P}^2}\rho_e. \tag{17}$$

The $n_e(\mu_e^*, T)$ and $\overline{n_e}(\mu_e^*, T)$ are the distribution functions for (anti-)particles with $E_e = \sqrt{\mathbf{k}^2 + m_e^2}$. Throughout this paper, we set $m_e = 0$ as done in the literature.

C. Mass gap multiplier with Thomson stability

The mass gap $m_{\gamma,P}^2$ is a Lagrange multiplier that enforces relevant physical dynamics constraints. The remaining task is how to determine this gap parameter reflecting the quantum fluctuating effects.

According to the general density correlation theory of statistical physics, the following identity should be fulfilled at the infrared singular critical point with strong fluctuation

$$\frac{\partial P_e}{\partial\rho_e}|_T = 0. \tag{18}$$

Therefore the total lepton number density has to make the system stable by minimizing the thermodynamical potential. We find that this crucial relation can be used to determine the unknown mass gap multiplier. Minimizing the thermodynamical potential of the leptons system(made of electrons and implicit neutrinos) stabilized by the external baryon background with the mathematically well defined effective potential or pressure Eq.(14) functional with Eq.(16)[2]

$$\frac{\partial\Omega_e}{\partial\rho_e}|_{m_{\gamma,P}^2,T} = 0, \tag{19}$$

one has

$$m_{\gamma,P}^2 = -\frac{e^2}{3}(T^2 + \frac{3\mu_e^{*2}}{\pi^2}) = -m_{\gamma,e}^2, \tag{20}$$

which is the negative gauge invariant electric screening mass squared obtained through the photon polarization Eq.(3) with the full electron propagator Eq.(17).

With some algebra operations, it is easy to find that Eq.(19) is also equivalent to the additional global $U(1)$ lepton conservation

$$\frac{\partial\Omega_e}{\partial\mu_e}|_{m_{\gamma,P}^2,T} = 0. \tag{21}$$

The physical meanings of Eq.(15) and Eq.(21) are quite different from each other. The former is thermodynamics relation identity, while the latter is the "mechanical" stability criterion. The relation between $m_{\gamma,P}^2(\mu_P^*)$ and $m_{\gamma,e}^2(\mu_e^*)$ can be confirmed by comparing Eq.(16) with that obtained for protons $A_0 = e/m_{\gamma,e}^2\rho_P$, by noting $\rho_e = \rho_P$ for the classical thermodynamics ground state.

The Eq.(20) is similar to the relation between the Debye mass and pressure for the ideal degenerate/quasiparticle gas derived with Ward-Identity responsible for the current conservation/gauge invariance[17]. The magnitude of the gauge invariant ratio $m_{\gamma,(e,P)}^2/e^2$ is the density of states for symmetric two component degrees of freedom with spin down and up. The contribution $\mu_{e,I}$ to the effective chemical potential characterizes the long range correlation physics, which leads to the phase space deformation of the particle distribution functions.

The thermodynamics properties can be learned from the underlying effective potential consequently. With Eq.(14) and the standard thermodynamics relation

$$\epsilon_e = \frac{1}{V}\frac{\partial(\beta\Omega_e)}{\partial\beta} + \mu_e\rho_e,\qquad(22)$$

the energy density functional is

$$\epsilon_e = \frac{e^2}{2m_{\gamma,P}^2}\rho_e^2 + 2\int_k E_e\left[n_e(\mu_e^*,T) + \bar{n}_e(\mu_e^*,T)\right].(23)$$

D. Negative pressure contribution

We analyze concretely the pressure $P_e = -\Omega_e/V$ at $T = 0$,

$$P_e = \frac{e^2\mu_e^6}{18\pi^4 m_{\gamma,P}^2} + \frac{\mu_e^4}{12\pi^2}.\qquad(24)$$

With Eq.(20), the pressure Eq.(24) can be reduced to

$$P_e = \frac{1}{3}\frac{\mu_e^4}{12\pi^2} = \frac{\mu_e^4}{12\pi^2}\left(1 - 286.9\frac{\alpha}{\pi}\right),\qquad(25)$$

in order to be compared with the analytical result expected by Kapusta in addressing the relevant compact object thermodynamics such as for the white dwarf stars mass correction resulting from the novel EM interactions of collective electrons. This non-perturbative calculation can readily approach to his anticipation about a very large negative contribution to pressure (the coefficient of the α/π term in Eq.(26) could have been $\sim 10^2$ instead of $\frac{3}{2}$[17]), but has no effect on the beautiful Chandrasekhar mass limit because this contribution has been exactly couneracted by the opposite charged system with strongly repulsive long range correlations.

What new physics can be found? Different from the weak coupling perturbative resummation result[17]

$$\frac{\mu_e^4}{12\pi^2}\left(1 - \frac{3}{2}\frac{\alpha}{\pi}\right),\qquad(26)$$

the analytical result Eq.(25) does not reply on the coupling constant $\alpha = e^2/(4\pi)$. The long range quantum fluctuation/correlation effects leads to the negative contribution, which is of universal characteristic. The induced negative interaction energy between the collective electrons can be as large as their kinetic energy and the transport coefficients such as the shear viscosity of electrons will be reduced significantly compared with the ideal/quasi-particle gas model although it is very hard to say electrons are in a superconductivity state.

IV. STRONGLY COUPLING LIMIT PHYSICS AND DISCUSSIONS

It is very interesting that the instantaneous strong Coulomb interaction between the like-charged electrons can be attractive in the dilute strongly coupling limit with the nuclear confinement effects. This can be confirmed from the negative scattering lengths between electrons obtained from the oscillatory stochastic Coulomb potential $e^2\cos(|m_{\gamma,P}|r)/(4\pi r)$ with the low energy Born approximation. The static Coulomb force between the itinerant electrons is modulated by the opposite charged nonlinear space-like baryon system, and so the electrons become highly turbulent and are confined to some extent. Like the effective fermion mass concept, the contribution $\mu_{e,I}$ to physical effective chemical potential characterizes the collective effects. This effect is more obvious by rewriting $\mu_e^* = \sqrt{m_e*^2 + \mu_e^2}$ at $T \to 0$. Assuming the global chemical potential μ_e fixed, the electrons will be effectively more heavy analogous to the Kondo physics[22].

Especially, the physics explored is quite similar to the quantum Ising characteristic BEC-BCS crossover thermodynamics studied with the Feshbach resonance in the opposite non-relativistic limit. Motivated by the underlying homology[23], the analytical universal factor is calculated to be $\xi = (d-2)(d+1)/d^2$ for d spatial dimensions through this counterterm analytical method. The result for $d = 3$ is exactly consistent with the Monte Carlo study[24]. Here, the ξ is the ratio of binding energy density in the strongly coupling unitarity limit to that for the non-interacting ideal fermion gas.

The surprising macroscopical like-charged attraction phenomena can be attributed to the hydrodynamic background effect[25] and the similar possibility is an interesting topic in current cosmology etc.[12]. Here, this counterintuitive quantum phenomena through an oscillating potential between the collective electrons is found from the point of view of the photon isospin mixing effects.

Before closing the discussion, let us stress that this is the quantum many-body effect, i.e, it is the density correlation/fluctuation leads to a refreshing long distance quantum dragging picture. Due to the presence of finite chemical potential in addition to the temperature Eq.(3), the Lorentz symmetry gets spontaneously broken in the medium which leads to the nontrivial mixing of vector and scalar although the rotation is still a good symmetry by noting that the spin angular momentum is a good quantum number. The nontrivial quantum transport of the strongly coupled electrons resulting from the derived effective attractive optical potential in the specific dilute pasta phase deserves to be further studied in detail.

V. SUMMARY

Mathematically, this two-photon counterterm approach is analogous to the general stability principle of the Newton's action-reaction law in mechanics. The screening corresponds to action, while antiscreening to reaction. Rewriting 0 as $0 = \frac{1}{2}m_\gamma^2 A_\mu A^\mu - \frac{1}{2}m_\gamma^2 A_\mu A^\mu = \frac{1}{2}m_{\gamma,e}(\mu_e^*,T_e)^2 A_\mu A^\mu + \frac{1}{2}m_{\gamma,P}(\mu_P^*,T_P)^2 A_\mu A^\mu$ and taking a bulk system as two opposite charged interacting subsystems through an external electrostatic potential con-

tribute to gauging/removing the infrared singularity divergences. The external source formalism makes it possible to deal with the interior long range fluctuation effects, while the perturbative Furry's theorem limit is evaded. In spirit, this approach is similar to the multi-grand canonical ensemble statical physics, which guarantees the physical constraint conditions, i.e., the gauge invariance, unitarity and the thermodynamics self-consistency.

In conclusion, we have analyzed the isospin mixing due to photon in the relativistic nuclear theory and take a two-photon method with HLS formalism to approach the strongly correlated charged multi-components fermion thermodynamics by taking the mysterious protons, electrons and photons as an example. The instantaneous RHA approximation and RPA techniques capture many of the non-trivial emergent phenomena which are crucial for understanding the collective effects in the strongly interacting charged systems. From the pure academic viewpoint of in-medium isospin and spontaneous Lorentz violation effects, the EM photon's role deserves to be further explored because "More is different" as said by P.W. Anderson[22]. This provides a practicable counterterm compensatory scheme to detect and gauge the infrared EM instability in a dilute strongly coupling system with either vanishing or nonvanishing net global electric charge chemical potential.

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